



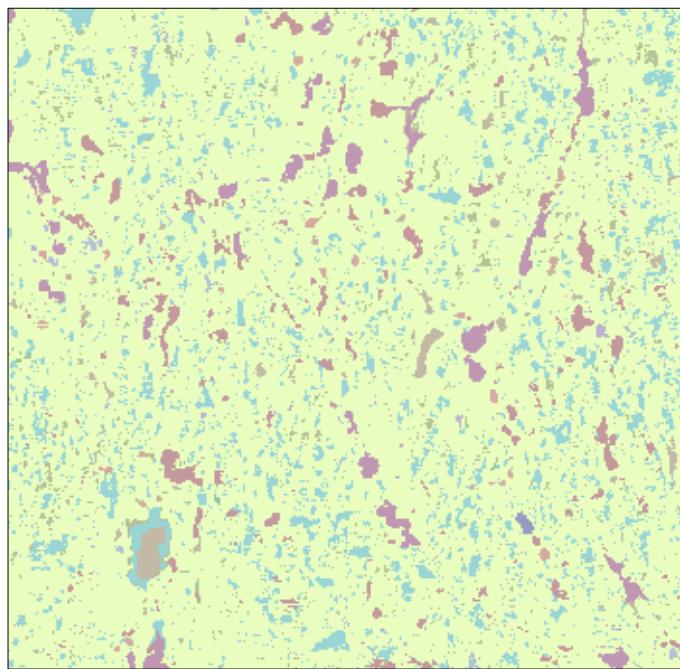
# Assessment of the vertical error in C-band SRTM DEM using data from Landsat-7 and ICESat

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# Background (1)

- Part of large resource group studying the Prairie Pothole Region (PPR) of Canada and U.S.
  - Millions of small potholes that are temporal or permanent in central plain of the North America
  - Interactions with waters, habitats, and human activities change the environmental system of the earth.
  - Example: breeding grounds for half waterfowl in North America
- PPR ecologically impacted
  - Destruction for agricultural crop production
  - Nutrient loading from agriculture and cottage developments
    - Water quality degradation due phytoplankton
    - Climate variability and change

# Location of Prairie Lakes



# Background (2)

- w/ remote sensing and GIS
  - Water budget anticipation with climate data
    - High density of drainage network, higher water budget
  - Water quality monitoring
    - Phytoplankton growth
    - Estimating N, P concentrations
  - Developing ecological model of process
- What we need?
  - Accurate topography/slope data for hydrologic study
  - GTOPO30, GLOBE (1 km), SRTM DEM, ...
  - Data validation

# Shuttle Radar Topography Mission

- Highly consistent accuracy global topographic data required for various aspects of hydrology.
- Known properties
  - Noisy water levels, voids, forests, etc.
  - Mostly no crops and tree leaves during mission (Feb. 2000).
  - Uncertainty in SRTM measurements
    - Larger number of geometric and radiometric corrections
    - Properties of radar backscattering and penetration
    - Antenna (baseline) behavior
- Data validation
  - w/ ICESat (Reference Data)

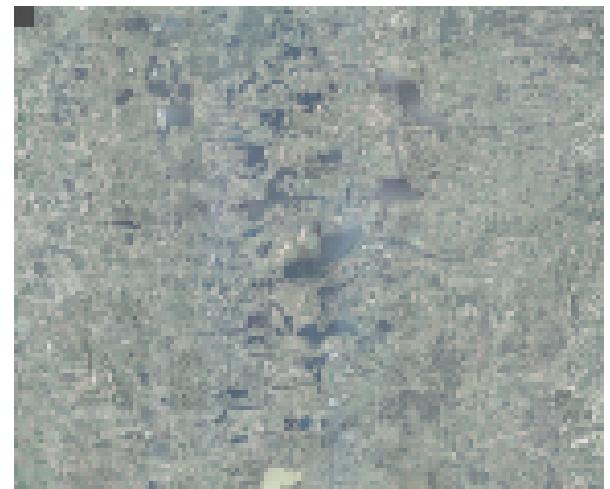
- Preliminary research on elevation accuracy by NASA
  - 70 m diameter and 175 m along-track footprints
  - Estimated accuracy is 15 cm.
  - Contains forest canopies
- Experience
  - Compared with on-site lake gage levels after conversion to common datum (WGS84 ellipsoid).
  - Measuring accuracy of GLAS on ICESat for lakes in MN was within 30 cm.
- Enough level of accuracy as reference for elevation comparison
  - At least one degree higher order accuracy is required.
  - SRTM DEM accuracy standard: 16 m absolute, 10 m relative

# Landsat, geologic units, & DOQ

- Geomorphological data
  - from Minnesota Department of Natural Resources
- Landsat-7 image
  - 30 m resolution
  - Aug. 2001
- Digital Orthophoto Quadrangle
  - 1 m resolution with natural colors
  - Used to identify land cover types



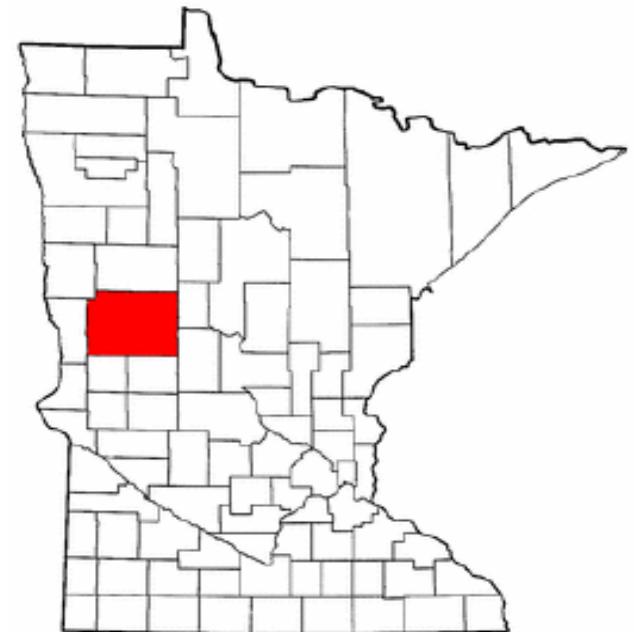
Landsat-7 (Jan 30<sup>th</sup>, 2000)



Digital Ortho Photo

# Study Area

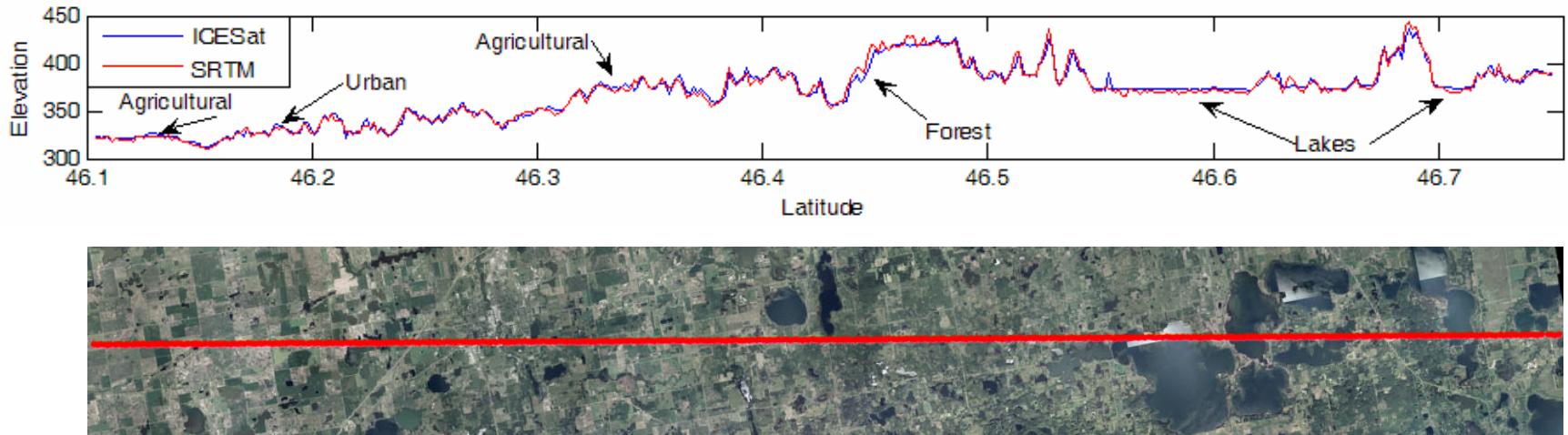
- Otter Tail County, Minnesota
  - Geologic features
    - **Outwash Plain** – Low relief, meltwater stream deposits
    - **Collapsed Outwash** – Moderate to high relief, melt water stream deposits that later collapsed
    - **Hummocky Moraine** – High relief, collapsed glacial deposits
    - **Ground Moraine** – Low to rolling relief, eroded glacial deposits
  - Land cover features
    - **Waters**
    - **Wetlands**
    - **Forests**
    - **Agricultural/Range lands**
    - **Bare grounds**
    - **Urban Areas**



# Processing

- Datum conversion was required for ICESat and SRTM DEM.
  - WGS84 ellipsoid
- Statistics were calculated by subtracting ICESat elevation data from SRTM DEM.
- Corresponding elevations to ICESat were interpolated from SRTM grid elevations.
- Mean
  - Represented as ‘bias’ or elevation ‘shift’
  - A deviation of SRTM elevation from the reference (ICESat)
  - (-) ‘under the reference.’
- Root Mean Square Error
  - Residual variation
  - Degree of fit of SRTM DEM to ICESat (SRTM-ICESat)

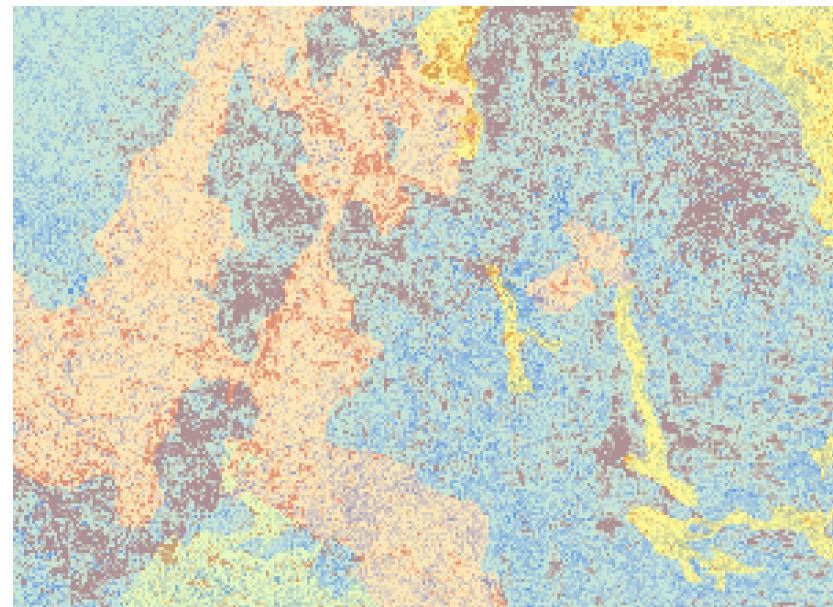
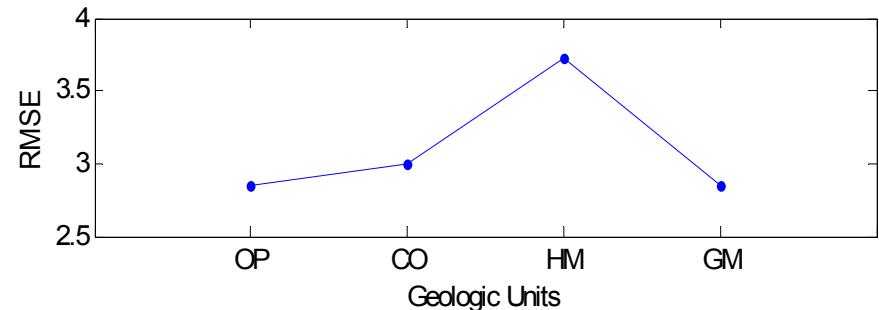
# Result



- SRTM DEM less reliable over lakes and forest areas
  - Random noise over lakes
  - More difference over forests
- Overall point data statistics with SRTM DEM (SRTM DEM – ICESat)
  - Mean = - 0.473 m and RMSE = 3.501 m

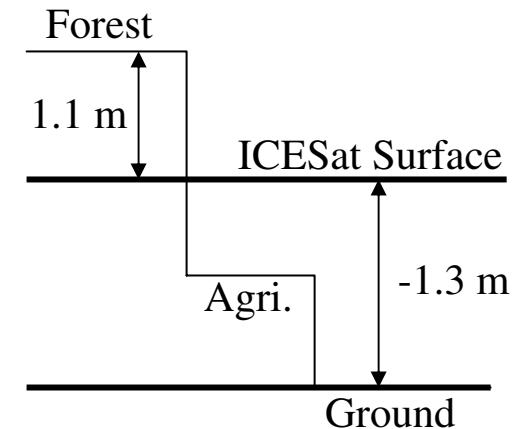
# Error Classification (1)

- By geologic units
  - Root Mean Square Error (RMSE) increasing with topographic relief.
    - Higher the relief, the larger the error.
    - Hummocky Moraine (HM) = 3.728 m
    - Others = 2.8~3.0 m
  - High relief area (HM) also more associated with the high forest canopies.
    - Red speckles (forest) in blue areas

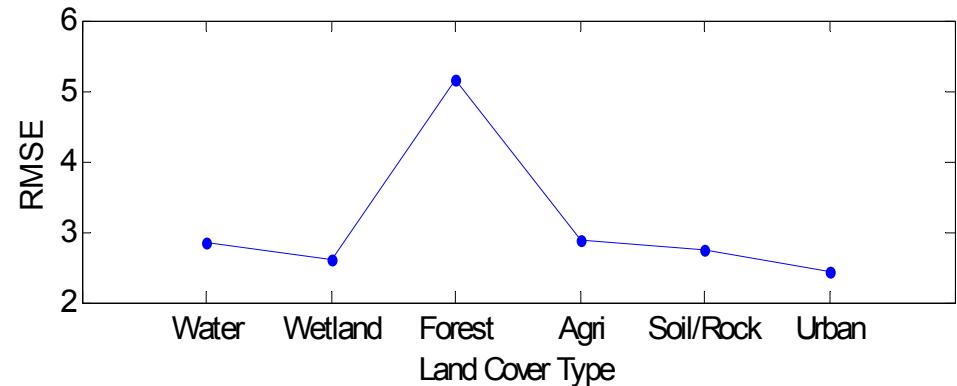


# Error Classification (2)

- By land cover types
  - Maximum error over forest areas.
  - Forest, agricultural land, and bare ground showed a typical trend in bias.
  - 1.1 m forest +1.3 m ground => 2.4 m canopy
    - Effective height of tree stems in winter
  - Temporal variation among datasets in agricultural area, therefore mean and error are problematic.
    - SRTM DEM in winter rarely includes vegetation but ICESat and Landsat in autumn.



Unit: m	Forest	Agri	Ground
Mean	1.092	-0.860	-1.301
RMSE	5.149	2.889	2.747
# of pts	705	1111	368



# Discussion

- Uncertainty of datasets
  - True land cover types on the date of mission can introduce errors by the classification of the Landsat image due to the time difference of both data.
  - The temporal variability among ICESat and SRTM can also produce errors.
  - Best result might be attained with a good temporal correlation on datasets but practically impossible.
- Penetration and geometric complexity of radar
  - Penetration of soil
    - Depending on the condition of soils (moisture, soil type, etc.)
  - Complex radar backscattering in the area with complex geometry such as forest and urban area

# Summary

- Topographic change on the surface is a factor of the errors of SRTM DEM.
  - High relief areas have larger errors.
- However, the errors also associated with the land cover types as well as the surface topography.
  - Larger errors in high relief areas are more affected by forest.
- Bias in each land cover type illustrates the elevation shift.
  - In this case, 1.3 m lower in SRTM DEM than the reference (ICESat)
  - Canopies need to be eliminated for the true surface for hydrologic studies.
- Ground Control Points with the High Accuracy Reference Network (HARN) supports the lower elevation of SRTM DEM.
  - Difference with GCPs ~ - 1.9 m